THE

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**Edited for the Council by J. LAURENCE PRITCHARD, Fellow.**

*All communications should be addressed to the Editor.*

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## Notices of the Royal Aëronautical Society.

**Lectures.**

Arrangements have been made for advance proofs of all lectures of the coming Session to be supplied on payment of 6d. each lecture or 2s. 6d. for the series of eleven (excluding the Juvenile Lecture). A complete list of the lectures together with an order form will be found among the advertisement pages. The first two lectures, on October 5th and 19th, will take place at the United Service Institution, Whitehall, S.W.1. The remainder will be held as usual at the Royal Society of Arts, John Street, Adelphi. All lectures commence at 5.30 p.m. except where otherwise stated.

**Pilcher Prize.**

The Council have awarded the Pilcher Memorial Prize for Students to Mr. S. H. Evans for his paper on "Some Notes on Commercial Aircraft" read at the Students' meeting of March 23rd, 1922.

**Examinations.**

The first examination for Associate Fellowship held under the new regulations will take place in the Society's Library on Monday (Part I.) and Tuesday (Part II.), September 25th and 26th.

**Students' Section.**

The following provisional programme for the first half of the next session of Students' meetings has been arranged:—

| | | |
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| Oct. 12th, | 6.45 p.m. | Annual Meeting and Election of Officers. |
| | 7.30 p.m. | Inaugural Address by Dr. A. J. Sutton Pippard. Chairman—Lieut.-Col. W. Lockwood Marsh. (This meeting is open to all members of the Society.) |
| Nov. 9th, | 7.30 p.m. | Mr. H. C. Brown, "Airships." Chairman—Lieut.-Col. W. Lockwood Marsh. |
| Nov. 23rd, | 7.30 p.m. | Mr. G. R. Irvine, "Some Practical Points in Aero Engine Design and Construction." Chairman—Major-General Sir W. S. Brancker. |
| Dec. 14th, | 7.30 p.m. | Mr. A. P. Rowe, "Navigation of Aircraft." Chairman—Sir A. Whitten Brown. |

All meetings are held in the Society's Library.

W. LOCKWOOD MARSH, *Secretary.*

# PROCEEDINGS.

## TENTH MEETING, 57th SESSION.

A meeting of the Society was held at the Royal Society of Arts, Adelphi, London, on Thursday, March 16th, 1922, the Chairman, Lieutenant-Colonel M. O'Gorman, in the chair.

The CHAIRMAN introduced Dr. V. E. Pullin (Director of Radiological Research, Royal Arsenal, Woolwich), who read a paper on "Radiological Inspection Work." Although, said the Chairman, Dr. Pullin put forward no claim to being a specialist in aeronautical matters, the investigation of the inside of materials would interest the members of the Society extremely. They would find the Paper very suggestive, and it might lead to developments in the direction of aeronautical safety, towards which they were striving, with every promise of success. He then called upon Dr. Pullin to read his Paper* on

## RADIOLOGICAL INSPECTION WORK.

The object of my lecture is to show the present position of radiology with regard to its usefulness in affording a means of inspection of various materials and more especially the materials and parts used in aeroplane construction. At the present time a good deal is written about X-rays and we who are working on the subject have to combat two extreme points of view—on the one hand the popular idea that X-rays can penetrate anything and on the other the idea that the whole subject is all very well as a laboratory piece of apparatus, in other words, a toy, but of no value whatever to the practical man.

I want to-night to show you exactly what X-rays are capable of doing now, what modern apparatus and technique can achieve and also what the limitations are and how far it will be possible for research to overcome them within a reasonable time. In the first place I will give you a general sketch of the activities of the Radiological Laboratory in the Research Department at Woolwich. The whole idea of radiological research there is to apply radiology as far as possible in every direction to the needs of the fighting services. We are not concerned at all with pure research for its own sake and only undertake such problems when they form a very definite means towards a practical service end.

The apparatus required for inspection purposes, which forms one of the main directions of work of this laboratory, is as follows:—

1. An X-ray tube capable of a heavy output of rays and designed to run for long periods.

2. A convenient high tension electrical transformer with a suitable rectifying device. For general inspection or factory use the installation should be portable, and perhaps most important of all, the whole apparatus must be absolutely safe both as regards X-ray and electrical dangers. Such a set, to have a maximum value, must also possess a simplicity of control in order that it may be put into the hands of comparatively unskilled workers. Fig. 1 illustrates such a set, which was designed for a specific factory purpose.

To consider now the general question of modern apparatus. It is not my purpose to discuss in any way to-night the physics of X-rays, I shall merely refer

* Synopsis only given.

to what are the essential pieces of apparatus required. A source of high tension uni-directional current, an X-ray tube, protection for the operator and also a method of registering the rays after passing through the specimen. For our present purpose we need consider only the high tension transformer as a source of high tension current, and as it may be taken generally that the penetrating power of the X-rays produced depends entirely on the voltage which is applied to the tube it is clear that transformer design affords a very large field for research in general radiology.

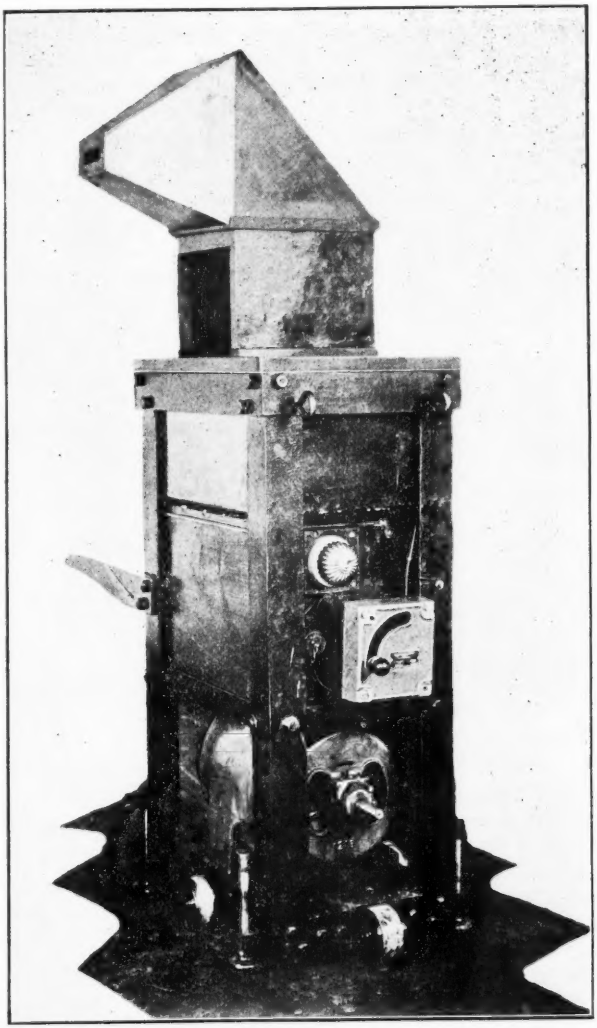

FIG. 1.

*Portable X-ray apparatus for factory or inspection use.*

For example, a transformer designed to give an (R.M.S.) voltage of 150,000 should, all other things being equal, enable us to penetrate three inches of steel and with modern technique should enable us to detect a flaw of about 1/64th of an inch. The current required for the operation of an X-ray tube must be unidirectional. It is therefore necessary to provide a device which shall rectify the alternating current delivered by the transformer. Here again is another subject for research.

The next and most important piece of apparatus is, of course, the X-ray tube itself, and if I had the time it would be possible to say quite a lot on this subject. However, I only propose to ask you to remember that the best type of tube for the work under consideration is that which is known as the hot cathode type in which the production of X-rays depends upon the emission of electrons from an incandescent filament. The great advantage of such a tube is that it is capable of very accurate control and it is more or less consistent in its performance.

The next point for consideration in an X-ray installation for inspection work is that of protection for the operator and workers from X-ray and allied dangers. In addition to the danger of shocks the presence of high tension electricity in the atmosphere is associated with certain obscure physiological conditions which may prove very harmful. It is therefore essential that all high tension apparatus should be carefully protected, and further that any room in which an X-ray installation is continually operated should be thoroughly well ventilated.

Regarding now the dangers due to X-rays, these are of the greatest importance because the physiological effect of the ray is not by any means understood. It is known that one type of X-radiation produces skin disease which does sometimes manifest itself in a severe form, but fortunately this particular form of radiation may be eliminated by a suitable system of screening.

There is another type of radiation which is produced at the same time which will penetrate a considerable thickness of almost any protective material and it is probable that these rays have a much more serious physiological effect, probably on the blood and deeper tissues. The problem is then to provide protection for the operator from the whole of this radiation.

The next item on the list of apparatus is perhaps one of the most important from the point of view of the practical man. It is the method of registering the rays. It is not necessary to refer here to the photographic method which, although valuable when examining certain of the heavier specimens, does not apply when considering the question of routine examination which has proved of so much service in aircraft construction. In this respect we need only consider the fluorescent screen which forms a means of rapid visual examination. The visual examination depends roughly on three factors:—

1. The screen itself.
2. The optical arrangement of the installation.
3. The physiological characteristics of the observer.

The choice of screen is important. X-ray screens in general are made of a coating of granular fluorescent substance on card or other material.

The fluorescent substance generally used is platino-cyanide of barium. Another cheaper but efficient type of screen is now made which is coated with a different fluorescent material and is known commercially as a white salt screen. The points about the choice of screen for this work are:—

1. Luminosity under the influence of the rays.
2. Contrast.
3. Granularity.
4. Fatigue.

Fluorescent screens vary considerably on each of these points. For instance, with regard to luminosity a difference of as much as 25 per cent. was observed

between one commercial screen and another. With regard to a comparison between the two types of screen referred to, there is very little to choose. Perhaps in general a platinum screen is superior, but this is more than compensated for by the far smaller cost of the white salt screen. The construction of the optical arrangements is important. Examination should always be made indirectly, that is, by means of a mirror. All light should be excluded as far as possible as the presence of stray light detracts enormously from the efficiency of observation. The physiological characteristics of the observer vary considerably. One man may prove to be an excellent observer while another may fail almost entirely to appre-

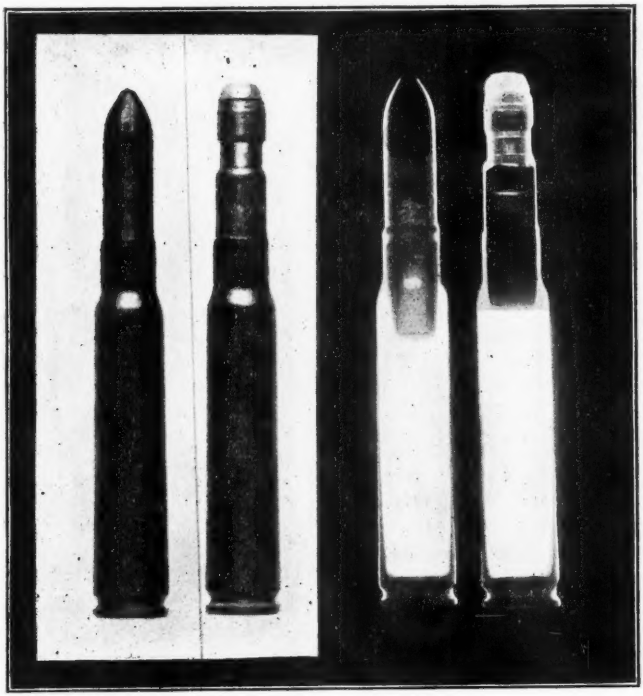

FIG. 2.

*German explosive ammunition. Left, photograph; right, radiograph.*

ciate fine detail. The eye may to a certain extent be rendered more sensitive by remaining for about five to ten minutes in the dark, but of course visual acuity varies considerably in different people. A good observer must possess an acute sense of contrast in illumination. It is a well-known fact that it is much easier to appreciate such contrast when illumination is brilliant than when it is feeble. Consequently we must aim at brilliant illumination of the screen, but this means a heavy current through the X-ray tube and at the present time really brilliant illumination of the screen is not possible when examining metal structures.

The research is proceeding along the lines I have indicated and progress in every direction is to be looked for, but at the same time the use of X-rays at the present state of development is certainly not properly appreciated. This applies more especially to you who are engaged in manufacture and inspection of aircraft which by reason of the lightness of the parts renders the radiological examination

comparatively simple. The one important essential is that skilled attention shall be devoted to suitable design of the installations.

Another point of noteworthy importance is that radiological examination is absolutely reliable. The enormous importance that attaches to the security, workmanship and materials of an aeroplane, a matter always of life and death, demands that no method of inspection which adds or may add so much to the security of the structure as a whole can be ignored without the fullest possible investigation.

Slides were then shown illustrating radiological inspection work.*

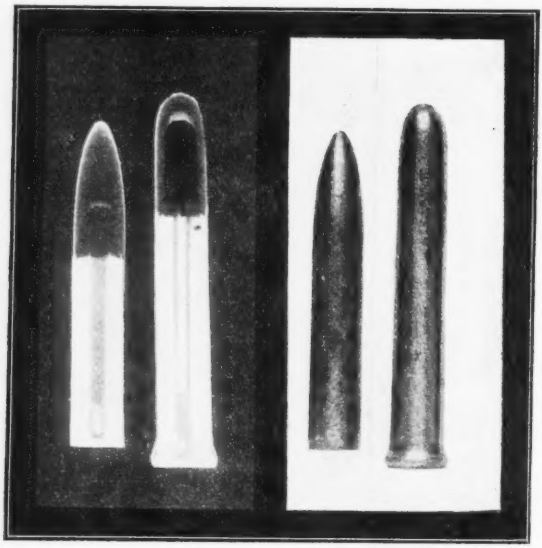

FIG. 3.

*German explosive cartridges. Right, radiograph; left, photograph.*

## DISCUSSION.

The CHAIRMAN, in opening the discussion, said he was glad the Arsenal was developing so useful an instrument for inspection purposes. Some seven years ago he had found in an aeroplane works not very far outside Paris a complete radiographic equipment, and had looked over it with interest, but the report he had got from this purchaser was that it was very dangerous and liable to give a malignant disease to those who used it; he himself was only allowed to peer into the room. No progress could be made by a firm using the apparatus without understanding. In Dr. Pullin's Paper we could see how precautions against the risks had been taken so as not to obviate the free use of X-rays for examination and testing.

Group-Captain E. F. BRIGGS said that any means which could be relied upon to show up cracks and faults in aeroplane parts was of great importance. Metal propellers were now being constructed, and a certain number had been in the air recently, and efforts were being made, by employing metal in lieu of wood, to

* It has been found impossible to reproduce many of these slides.—EDITOR.

overcome the effects of heat in the East. In this connection a large amount of welding was employed, and as far as he could see, examination by means of X-rays would be most useful if it could be carried out in general practice. He was doubtful as to whether, at the present time, it would be practicable to put down a plant at each works, or whether it would be possible for the Aeronautical Inspection Department to transport plants in order to make special examinations. As regards other parts of metal aircraft, such as spars and ribs, at the present time one did not resoft to welding, these were nearly all rivetted, and he doubted

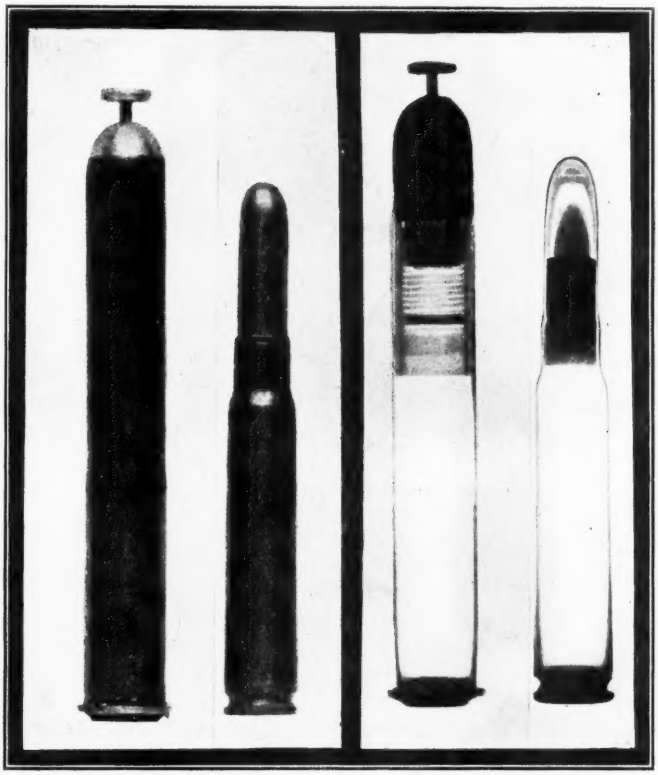

FIG. 4.

*German explosive ammunition. Left, photograph; right, radiograph.*

very much whether radiological inspection would do much good in that connection. He asked the Lecturer what would be the cost of installing plants which would deal with such items as propellers, because that at the moment seemed to be rather a governing factor.

Mr. W. O. MANNING agreed that such an apparatus would be of considerable use in connection with the examination of welds. With regard to many of the specimens shown on the screen, the trouble could have been found out by ordinary visual inspection, and he was of opinion, therefore, that for ordinary purposes the system was rather too complicated. There would appear to be some difficulty

in the interpretation of results when they were obtained, if the radiograph showed a curious marking it did not seem obvious what it was. It might be a flaw, or some slight trouble which was not detrimental in a particular part, or it might be an exceedingly serious matter. Again, he understood that if a crack were

FIG. 5.
*Lead letters R.D. radiographed through 3 inches of steel.*

edge-ways on the apparatus, it could be seen quite clearly, but if it were the other way round it was possible that it would not show up at all. It might therefore be necessary to examine all specimens on all three planes. He considered the difficulty of interpretation as very serious. It must depend to a large extent on the judgment and experience of the operator. This experience could only be obtained by com-

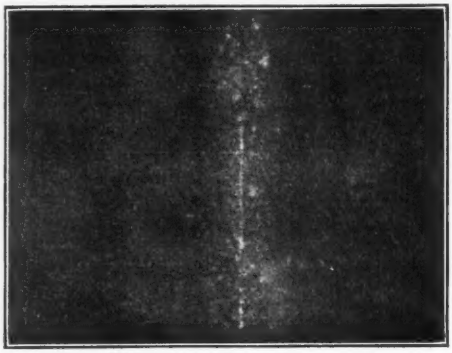

FIG. 6.
*Weld in steel plate ½ inch thick.*

paring the appearance shown in the radiograph with the actual fault discovered after the specimen has been cut up. Before the process can be used a supply of trained operators must be available, and it does not appear that they exist.

Major CARTER asked the lecturer whether it was usual when examining a specimen to turn it at right-angles, in order to get an inspection in two dimensions, and whether any work had been done by Dr. Pullin on aircraft engine parts, such as crank cases or welded cylinder heads.

Dr. G. W. C. KAYE (National Physical Laboratory) expressed his appreciation of the work carried out at Woolwich. Some of the photographs which had been shown were very beautiful, especially those dealing with munitions of war. As regards aircraft, the first work on this was done during the war by the Aeronautical Inspection Department in association with Dr. Knox. Some of the results were published before the Faraday Society in 1919. The Air Ministry had an outfit installed at the N.P.L. at present, and a certain amount of work had been done there. One of the reasons why radiology had not made such progress in engineering as it might have done was the present state of development of both apparatus and technique. We were, as regards X-rays, in a sort of "farthing dip" era, and we had a long way to go before X-rays could be popularised in the commercial world. The apparatus had got to be far more powerful, and the X-ray bulb improved out of recognition. There was in fact a great deal of work to be done, and progress could only be made through continuous research. He warned his hearers, however, that results must not be expected too soon, investigators must be given a chance.

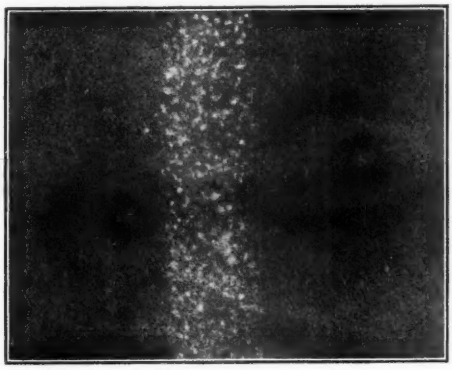

FIG. 7.
*Weld in steel plate 1 inch thick.*

Colonel C. R. B. OWEN (War Office) said that the photographs of fuses, detonators and things of that sort were very suggestive to anybody interested in small arms ammunition. Whether radiology in this connection would be really applicable it was beyond him to say, but during the war there were many things in connection with which the apparatus would have been a help had they been able to apply it suitably, such as the presence of two bullets in a cartridge case, and the omission of the powder charge, troubles which in many cases were believed to be due to deliberate action. During the war cases even occurred of foreign substances being inserted into the cartridge in place of the charge, which made detection of a faulty cartridge by weighing very difficult. An apparatus of the nature under discussion might, in certain circumstances, be useful in detecting such faults, but from the practical point of view the great amount of ammunition that has to be handled in a large war would preclude its general use. Should it be possible however to produce a plant for say £20 such an apparatus might have a value in special cases.

Dr. PULLIN said he thought so. Where inspection was to be economical, it might be possible in some cases to modify a specification. For instance, in the case of the filling of a small arms cartridge, the inclusion of a very small percentage of opaque salt, barium salt, would pay from an inspection point of

view, because that would enable large numbers to be passed through a screen at once. It need only be a very small quantity, which would not interfere with the explosive property of the filling, but would render the filling opaque.

Mr. Bowden (Chief Superintendent, Ordnance Factories, Woolwich Arsenal) said the picture that had interested him most was that showing an insulating material. Although it had no direct bearing on aeronautical inspection, it did show how far X-rays might be of service. It was not clear from the picture how far the method was an ordinary workshop process. When one commenced mass production, one necessarily needed a means of inspection of the materials used. The picture method of inspection had proved particularly helpful during the war, and radiology was now on the way towards facilitating examination in large

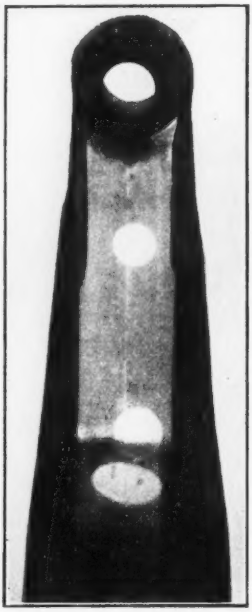

Fig. 8.
*Radiograph of U-tube socket, showing faulty weld. The weld was apparently sound, but radiograph shows want of union between the parts.*

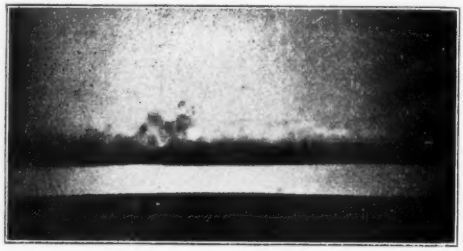

Fig. 9.
*Faulty weld in petrol tank union.*

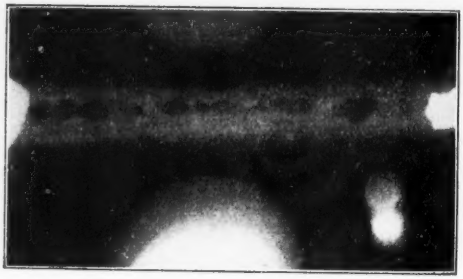

Fig. 10.
*Faulty weld in interplane strut socket.*

quantities. It was much quicker to pass pieces inspected over the machine than to inspect them by the manipulation of tools. There was another point, which was perhaps apart from pure inspection. The inspection referred to that evening was mainly for the purpose of safeguarding against improper functioning, against danger, and so on, but he himself could see a very wide field for radiology in the direction of saving money. If Dr. Pullin and other investigators could increase the penetration of the rays so that they would go through 6ins. of steel, great economies could be effected in connection with the inspection of ingots, and it would be of great benefit to the manufacturer. He asked Dr. Pullin whether the voltages in relation to penetrating power were on curves which ascended in parallel,

or whether they were not like the speed of a ship, in connection with which, as the knots were increased, one had to cube the engine power, or something of that sort. He hoped radiologists were not going to lead us to that, because, if that were so, the enormous voltage which would be required to penetrate 6ins. of steel would land us into the region of electrical pressures which we would all be afraid to go near.

Mr. CAMPBELL spoke as one of the much maligned inspectors of aircraft. At the present time inspectors had quite enough trouble to contend with without going to a contractor with an X-ray apparatus; any contractor would shoot them at sight if they appeared at his works with such a formidable weapon. There had

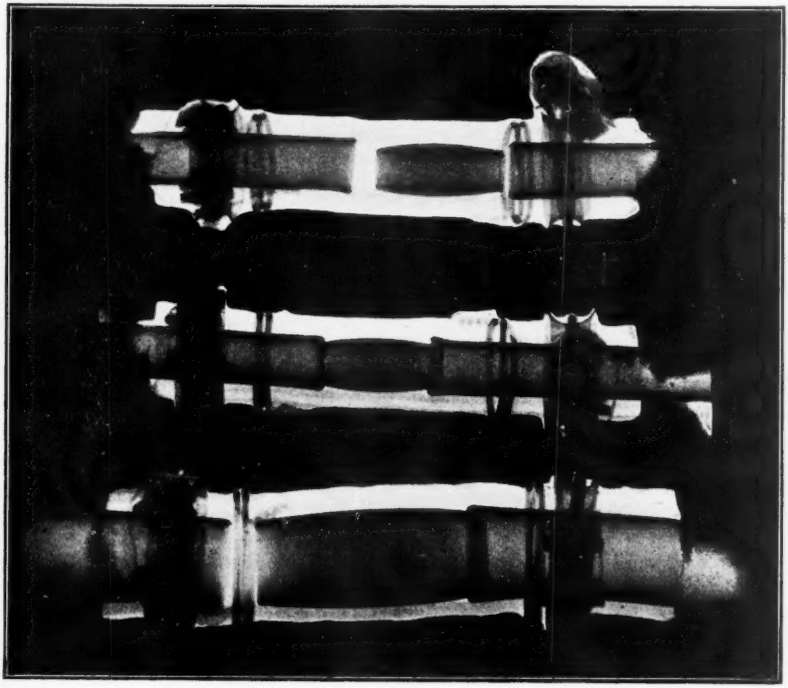

FIG. 11.
*Radiographs of rubber pipe joint, showing correct and wrong positions of the internal metal sleeve.*

been one or two examples of faults in timber shown on the screen, and there was one showing a case of particularly pronounced cross grain. If he had an inspector who could not immediately spot cross grain, or what was more difficult to spot in timber, namely, spiral grain, he would fire him at once. He agreed with the second speaker that there were in addition quite a number of the examples shown in which the faults could be seen quite easily by a straightforward examination. Unfortunately, there were times when these faults were not to be seen so readily. The main faults they had to contend with were fakes; a workman made a mistake, and purposely faked the job, in order to make it look all right, and he agreed that no ordinary human inspector could readily find a fault in such a case. If one suspected such a fault, then he contended that X-rays would be a

help, but, unfortunately, one did not know just when and where to look for a criminal fake. The control column shown on the slide was a case in point. As the end of the socket was open, a man, provided he examined the control column as such, could see whether the tube was bedded down or not, but if the control column were fixed in position on a machine it would be difficult for him to see such a fault. In the bedding of timber struts into sockets, if the struts were carefully fitted, the chances were that external examination would give some idea of whether they were bedded down or not. At one time they advocated inspection holes at the bottom of all sockets in order to see whether struts were adequately bedded down, but he was of the opinion that inspection holes tended to induce a workman to fake a job so as to look all right.

Group Captain Briggs had mentioned metal propellers, and he himself had had a little to do with their development on the manufacturing side. The problem had been, not so much the difficulty of getting a sound weld as the difficulty of getting a sound structure of the material after the heat treatment of the blade as a whole. That had been the main trouble, and he was certain that no X-ray outfit would be able to give any indication of the structure of the metal itself.

Mr. C. H. HOLBEACH (British Thompson-Houston Co., Ltd.) asked what milli-amperage and what voltage the Lecturer had used in order to obtain sufficient light on a fluorescent screen to enable him to examine visually half-an-inch of steel. His reason for asking was that in all probability the use of a tube that would stand up to the powers necessary for that purpose would entail water cooling of the anode, and it should be borne in mind that the application of X-rays to industrial purposes presents a totally different problem to its use in a research laboratory. This is of particular import in considering the X-ray tube employed. The failure of the tube, whether by breakage or loss of vacuum in a laboratory, would not be a disastrous occurrence, because it is an easy matter to re-exhaust the tube with the plant which a laboratory of this nature would have at its disposal. Moreover, the exhaust pump can be permanently connected to the bulb. On the other hand, in the industrial application of every-day examination of metals the question of using the right apparatus with a high-powered tube is an important one. At the present moment no available tube would, in his opinion, stand up to the energy that would have to be passed in order to fluoroscopically examine half-an-inch of steel.

The CHAIRMAN said he did not feel as critical as some speakers had shown themselves to be as to the prospects of radiography in engineering, because, although many had alluded to the fact that the radiographic apparatus would help the inspector, some speakers had forgotten that the manufacturer would take care to have a radiographic apparatus of his own, and even if some wily person used barium paint to darken light places, progress would result from the introduction of the apparatus and its use. He felt that in the long run it would be a very valuable instrument indeed. As regards defective welds, if the radiograph would really disclose what were sound welds, welding might yet be allowed back into aeronautics with advantage to everyone. The radiograms of defective welds shown that evening had indicated quasi-mechanical defects such as butt joints that were not butt-jointed, but they did not, he thought, indicate the other trouble which had been found in welding. The heating of the metal close to say, one millimetre from the weld to a certain temperature, was not infrequently found to reduce locally a tensile strength of 25 tons down to a tensile strength of about 10 tons over a narrow belt. Therefore, the strength of the piece was so greatly reduced that it ought not to occupy a position of stress. If the radiograph could distinguish between steel at 10 and at 25 tons tensile strength it would be a priceless instrument, but he doubted whether it could be brought to do so. On the whole, the bringing of X-rays into use was a thing which aeronautical engineers should welcome. They were always dealing with the ultimate limit of strength, and cutting away to the finest possible degree, and there seemed no doubt that, since so

much depended on a mistake, which might be either viciously or accidentally made, any really far-reaching weapon which looked into unseeable places would be of immense advantage.

Dr. Pullin had asked that he might be allowed to reply to the discussion in writing, because he had an appointment to keep. In conclusion, the Chairman moved a hearty vote of thanks to Dr. Pullin for his interesting and suggestive Paper.

## REPLIES TO CRITICISMS.

In reply to Group Captain E. F. Briggs, certainly one of the most generally valuable applications of X-rays was to be found in the examination of welds from the point of view of general soundness of the weld and also the development of blow holes and cracks. It would be of advantage if I could be furnished with specimens of the propeller welds mentioned by Captain Briggs, I could then more accurately suggest the figure involved in the design and construction of a suitable installation. It might prove of great advantage if a general X-ray outfit were installed in every aeroplane factory which could be adapted by means of specially designed viewing screens and suitable controls to serve many purposes, not necessarily for routine work only, but which could be used in all special and doubtful cases. Such a set would call for very careful and economical design, and should not cost more than £200. I should be very happy to consider such a set, and go more carefuly into its general use. With regard to rivetting, X-rays can certainly be of use here, not only with regard to examining unseen parts for, say, the presence and proper functioning of rivets, but with suitable technique the fit of rivets can be examined.

In reply to Mr. W. O. Manning, the object of the lecture was perhaps slightly misunderstood by Mr. Manning. The question as to whether the objects shown on the screen were detectable by visual examination does not matter in the least; the idea of the pictures was to show how defects were shown by X-rays. I want members of the audience to submit specimens, of which there must be a large number which defy visual examination. This surely is possible, judging by the number of cases where visual examination has actually failed, sometimes with disastrous results. I want to make it quite clear that the specimens shown were not selected necessarily as definite suggestions for actual examination, but to illustrate the sort of result that could be achieved by X-rays. With regard to the interpretation of the radiographs a man could very easily be taught what the various shadows mean. Radiographs are nothing more or less than shadows pictures, and the shadows merely indicate differences in density.

In reply to Major Carter, I am not aware of any work having been done on the radiographic examination of welded cylinder heads or crank cases. It might be of interest to point out here that, at the present stage of development, hair cracks in steel are not possible of detection by X-rays. In the work at Woolwich specimens were always examined twice, one examination being from a point at right-angles to the other where practicable.

In reply to Dr. Kaye, I quite agree with Dr. Kaye that X-ray research has a long way to go before it achieves all that we who do research work on the subject believe it is capable of achieving in the commercial world. I am also grateful to Dr. Kaye for emphasising the fact that results must not be expected too soon. Radiology is an expensive and laborious work and the workers are very few, but the progress that has been made and the enormous importance of the subject, demand that every facility should be given to help work that will certainly ultimately result in great economies, and what is more important from the point of view of aircraft, very greatly increased safety.

In reply to Mr. Bowden, the examination of electrical insulating material by X-rays is of the greatest possible value and certainly could very easily be made

an ordinary workshop process. The application of radiological examination to mass production is often merely a matter of careful design of special X-ray apparatus to deal with the particular article to be examined. In suitable cases such inspection can be very rapidly carried out. As an example of this I might mention that such an inspection of many thousands of a certain small service store has been carried out at Woolwich at the rate of 2,000 a day and at a merely trifling cost for materials. This work was done on the ordinary research installation. With specially designed apparatus and proper organisation for handling large quantities, this total could be considerably increased. No other means exists of ascertaining the internal condition and consequent safety of this particular store and had radiological methods not been available it would have been necessary to destroy the whole supply. The examination of large thicknesses of metal certainly requires the use of higher voltages, but the situation is not so alarming as suggested by Mr. Bowden. It must be remembered that from the practical point of view, a great deal is to be obtained by increasing the current carrying capacity of our X-ray tubes, and work in this direction is in progress.

In reply to Mr. Campbell, my remarks in reply to Mr. Manning would apply generally here. I would merely add that as research progresses X-rays will become more and more useful as a means of accurately examining materials and the manufacturer will have to realise that a very formidable instrument is becoming available for examination purposes. At the present time perhaps it is neither economical nor desirable to employ X-rays as a routine method of inspection, but undoubtedly an installation in an aircraft factory for isolated reference would even now prove very valuable always provided that the installation were properly designed and sufficiently adaptable. Any method which will enable an inspector to " see " inside a specimen and examine it under conditions that inhibit ordinary visual inspection is obviously a thing of high potential value. It remains to develop the method until it becomes indispensable. At present suggestions are urgently wanted to assist that development. Negative criticism has hardly the constructive value that is so essential to progress.

In reply to Mr. Holbeach, 10 milliamperes and the voltage corresponding to an alternative point spark gap of 10ins. operated under suitable conditions. The source of current was an oil-immersed closed core transformer. The experiments referred to were all carried out in a research laboratory.

In reply to the Chairman, I should in the first place like to thank him for his very illuminating and helpful remarks. The object of the lecture, as I have said before, was to elicit from an audience of specialists the directions in which the development of X-rays would have a maximum value. I would like to remark in the first place that there is no difficulty at present in designing an X-ray set that shall be perfectly safe. With regard to welding, X-rays do afford at present, within certain limits, the only really satisfactory method of examining welds as such. Concerning the changes in the metal which are produced by the heating necessary in welding, I do not think that simple radiographic examination will ever be of much value, but various research workers are at present tackling the problem by means of X-rays in another manner. I refer, of course, to X-ray crystal analysis on the lines of the methods introduced by Debye and the Braggs. It is early yet to speak of particular progress, but the results are, on the whole, very encouraging, and certainly inspire the hope that radiology will afford valuable aid to the metallurgist, especially perhaps with regard to information about changes in metals due to heat treatment.

# SOME TECHNICAL ASPECTS OF AVIATION IN CANADA.

BY E. W. STEDMAN, FELLOW.

## INTRODUCTION.

Before dealing fully with the technical side of aviation in Canada it is advisable to discuss the different kinds of work that can be carried out by aircraft in this country. A few of these duties are described below.

### Forest Insect Investigation.

In forest areas it is sometimes found that insects are attacking and destroying the timber, but it is generally difficult to determine the extent to which the insects have attacked the timber and the direction in which the pest is advancing. It has been shown that by flying over the forest area affected a trained forestry observer can decide at once where the insect pests have been at work and the direction in which the trouble is proceeding, so that he can form an opinion as to where any protection measures should be applied.

Recent experiments in the United States have shown that in some cases the pests can be dealt with by poison distributed from an aeroplane.

### Forest Reconnaissance, Forestry Photography and Forestry Survey.

In any new country the extent, size and nature of the timber can be quickly determined, photographed and sketched on existing charts or maps by forestry

FIG. 1.
*Photograph illustrating forestry reconnaissance from the air.*

observers working from an aeroplane, and similarly the organisation and conduction of logging operations can best be directed by an observer who has viewed the whole situation from the air.

**Fire Detection and Transportation of Fire Fighters.**

It is recognised by everybody that is interested in the subject that the prevention or early suppression of forest fires is a subject that requires a tremendous amount of attention and care. With the usual methods of forest patrol, in which the observers make use of existing water-ways, it is not always possible to observe a forest fire in its initial stages as the fire may occur in districts not easily observed from a water-way; also the district under observa-

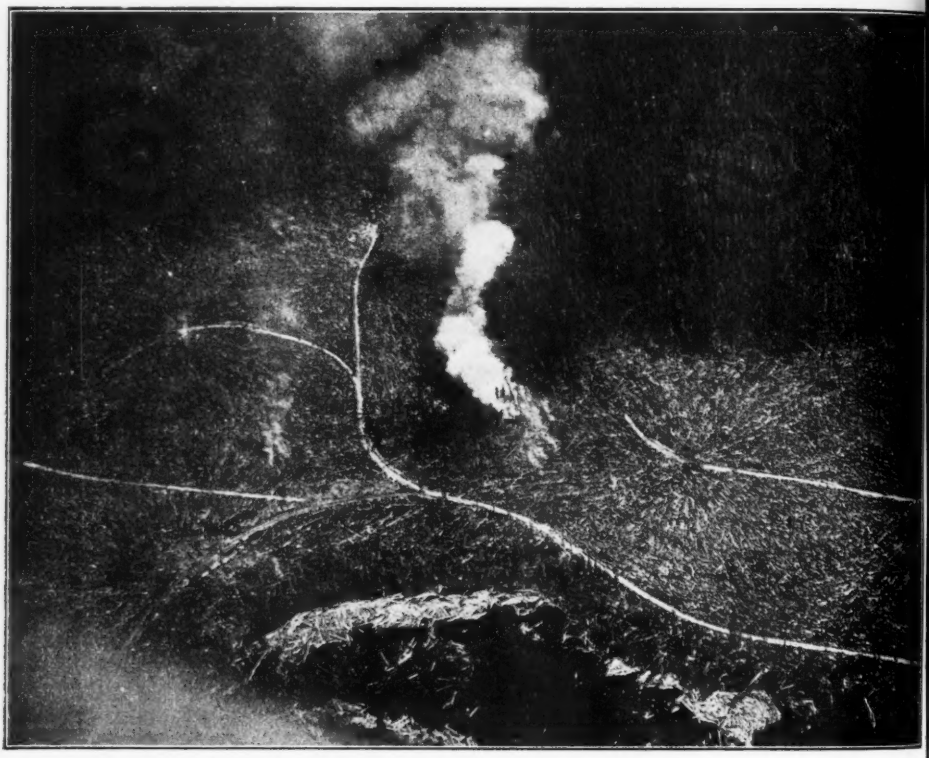

FIG. 2.
*Photograph illustrating detecting fire from the air.*

tion by an observer at any one time is small. Similarly, the observation posts erected for forest protection will usually have a fairly limited outlook, but by carrying out forest patrols from the air it is possible for the observer to have an enormous tract of country under observation at any one time, and further, the smallest indication of smoke is noticed immediately, with the result that it is more frequently possible to conduct fire-fighting operations before a fire has attained any size. The moral effect of an air patrol on settlers or campers is in itself a large contribution towards the elimination of forest fires.

If a forestry observer patrolling by canoe finds a large fire, it is usually necessary for him to return to some base in order to obtain the necessary help. This double journey occupies a large amount of time, during which the fire may have increased considerably in magnitude.

In forestry patrol from the air the procedure is different. If the fire is small, the seaplane is landed at the nearest lake or water-way and the crew proceed to the scene of the fire. If they are unable to cope with the fire themselves, they leave one or more men and return at once to the base for assistance. The seaplane returns with extra men, food, etc., and keeps up

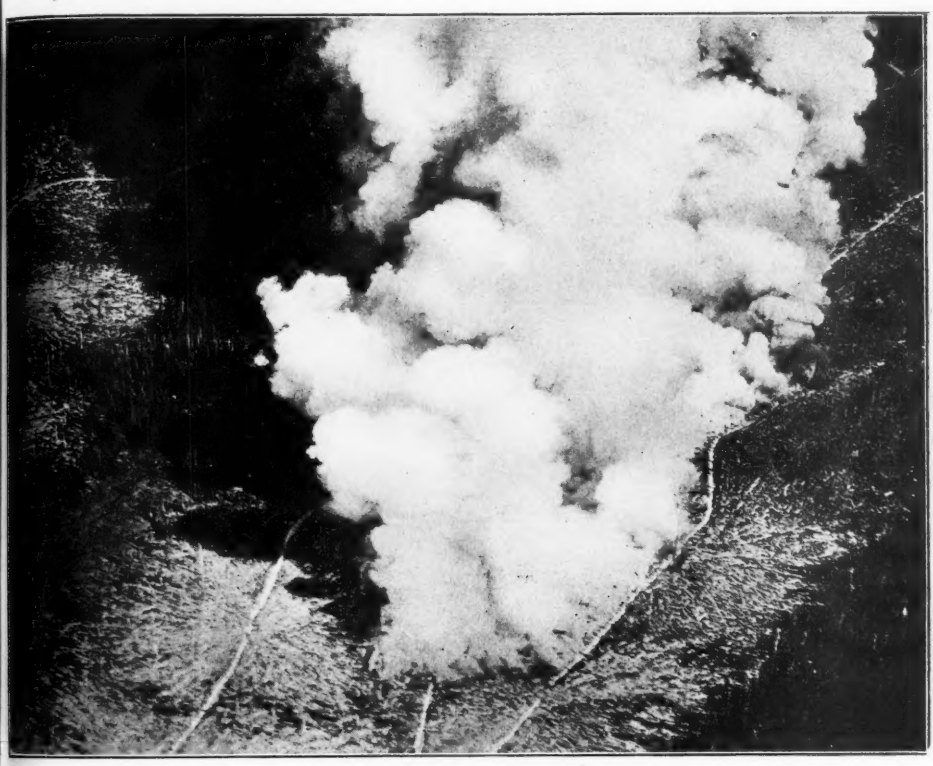

FIG. 3.
*Photograph illustrating detecting fire from the air.*

communication with the base as long as the fire fighting is in progress. As soon as the fire is under control the fire-fighting crew is carried back to the base and is ready at once for any other emergency, or they may be transported direct to another district.

**Water Power Reconnaissance.**

In deciding upon a water-power scheme it is often necessary to obtain particulars of some part of the country that is not well mapped in order to determine the watershed area and details of the direction of flow of water. For this purpose there is no method which is more convenient than the air for

obtaining the information required, as a comprehensive grasp of the whole situation can be obtained in the course of a few short flights.

**Survey Reconnaissance and Transportation of Surveying Parties.**

In carrying out primary triangulation of mountainous country it has been necessary in the past for the survey parties to lay out roughly the figure desired and then to select mountain peaks which might prove suitable for stations. Having selected these peaks it is necessary to climb to the top of each of the peaks in order to see that the range of vision is such as is required for a station,

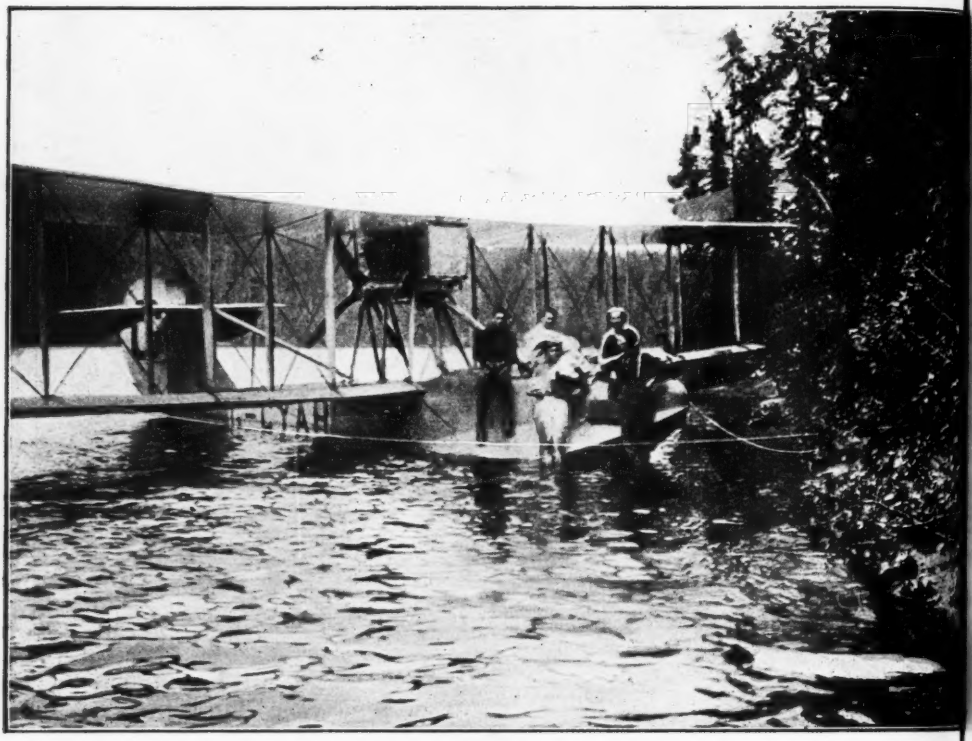

FIG. 4.
*Transportation of fire fighters.*

and if not, a different peak has to be selected and climbed before the position of the station can be decided upon. Under the conditions used in the past it has always been a matter of doubt as to whether the figure obtained was the best possible in the country or whether something better could not have been found by spending more time in selecting the stations. The whole procedure can be proved and expedited by the use of aircraft, as it is possible for the man in charge of the surveying party to be carried over and around all the peaks in the neighbourhood of which he wishes to place a station so that he can obtain at once an idea as to which of the peaks is suitable for the station and so save an enormous amount of time that would otherwise have been wasted in climbing difficult and dangerous peaks. Also he can select a better figure

for his triangulation, as he is able to inspect a much larger number of peaks. Having decided on the position of his stations the aircraft becomes of primary importance for carrying the parties to their respective stations and keeping up communication between the parties and their base by carrying in supplies, etc., thus saving a large amount of time that would otherwise be wasted in packing and transportation.

FIG. 5.
*Photograph illustrating survey reconnaissance.*

FIG. 6.
*Photograph illustrating survey reconnaissance.*

**Geological Reconnaissance.**

In opening up new country it is necessary to send out geological parties, who prepare geological maps of any particular part of the country. This process occupies a large amount of time as there may be very large tracts of a geological formation that is of little interest but which the party have to traverse. It is well known that geologists can roughly divide up the country into different formations by obtaining a bird's eye view of the nature of the country. If the geological reconnaissance party is carried by air they can be rapidly transported over country on which there is no change of formation and landed at any point at which there appears to be a change in the geological formation or other matter

FIG. 7.
*Transport of survey parties.*

of interest. In this way preliminary geological surveys can be very rapidly accomplished.

**Waterway Photography, Waterway Reconnaissance, Harbour Board Photography.**

A large number of rivers have in them sand-bars which are continually changing their shape and position so that in such a river navigation is always liable to obstruction due to change in the position of a sand-bar. Aerial photographs have shown that sand-bars in a river can be very accurately mapped from the air, and in connection with water-ways of this type a considerable amount of worry and expense could be eliminated if photographs of all the sand-bars or other obstructions were taken periodically and issued in a form that would be of assistance to navigators.

In connection with harbours, similar work could be carried out.

**Photographic Survey of Cities.**

From time to time several mosaics of cities have been made, and these have shown the importance of different branches of aerial photography from the point of view of the town planner.

Customs Patrols; Reclamation Reconnaissance; Fishery Protection; Scenic Photography; Cinematograph Photography; Passenger Carrying between Cities; Passenger Carrying Joy Riding; Photography of Factory Plants; Exhibition Flying; and Naval and Military Flying need no comment except that for service purposes the necessity for flying all the year round is emphasised, and last but by no means the least, *mail carrying and express freight carrying*, which also requires a year round service.

FIG. 8.
*Photograph illustrating geological reconnaissance.*

## COUNTRY TO BE TRAVERSED.

In so far as aviation is concerned, Canada can be divided into two districts:

(1) The prairie country, extending from the foothills of the Rocky Mountains east as far as Winnipeg, north as far as Edmonton, and south to the international border.

(2) The remainder of Canada.

The first district consists of rolling plains, on which land machines can find landing grounds with very little difficulty.

The remainder of Canada is largely filled with lakes, with the result that a seaplane or flying boat is the most suitable type of machine for summer use.

The extent to which the lakes intersect the country cannot be realised until large-scale maps have been examined in detail, or better still, the country has been flown over. Under these conditions it is at once realised that in almost every district lakes suitable for landing on are available, but in the more mountainous districts a good performance machine is necessary in order that the high land can be negotiated after the water has been left. Enormous tracts of land

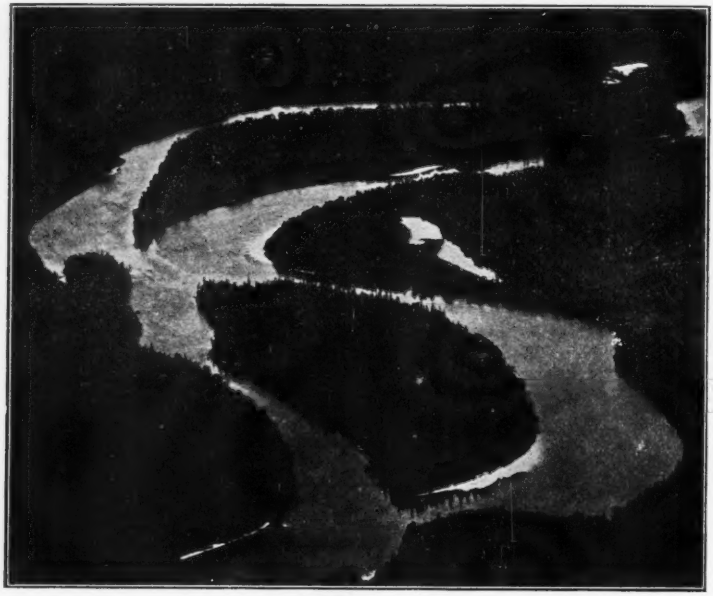

FIG. 9.
*Photograph illustrating waterway survey.*

to the north of the railroads can be patrolled, surveyed, or otherwise developed by the use of seaplanes during the months that the waters are open to navigation.

The question of flying in these districts during the winter months is one worthy of the serious attention of aeronautical engineers, as the conditions which occur in the north part of Canada with its enormous undeveloped natural resources are the same as occur through very large tracts of country in Asia and Russia, which are also known to possess large undeveloped natural resources, and which the advance of civilisation will demand to be developed.

It is only necessary to realise the area of timber and mineral-producing country of the Ungava, which forms the larger part of the Quebec Province, and the wealth of the McKenzie River Valley to see the importance of developing rapid transportation for exploration, prospecting and surveying parties, etc.

During the summer months the problem is simply one of organisation, financing, etc., the engineering part being the same as would occur on any other seaplane route in a temperate climate; but so much more could be done if transportation could be carried out the year round, and with this object in view any research work that has been carried out in Canada has been mainly directed to the solution of problems connected with winter flying.

FIG. 10.
*Photograph illustrating harbour survey.*

Canada is the only portion of the British Empire in which the problem of winter flying can be systematically studied, but the results so obtained would be of value to the rest of the Empire.

## TYPE OF MACHINE.

For summer flying, in a large part of Canada a flying boat will meet most

requirements. It has been found that for forest patrol and reconnaissance it is desirable to carry about five people made up as follows :—

One pilot.

One photographer.

Two forestry observers, who sketch and make notes of the country passed over (one from each side of the machine); and

One mechanic.

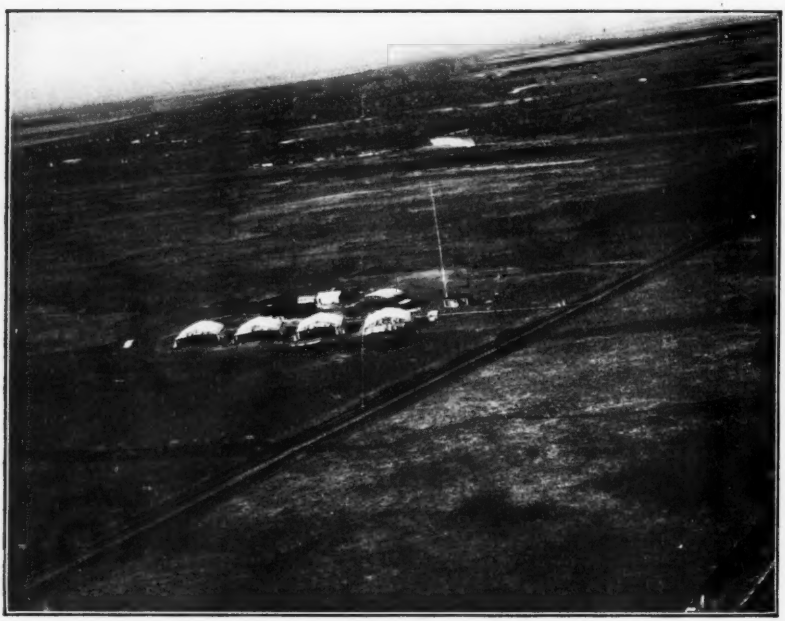

FIG. 11.
*Aerodrome in prairie country.*

It is also desirable that the machine should have capacity for fuel for six hours' cruising, although this may not necessarily be carried with a full load of passengers and their gear. One essential point to remember is that when quite light, that is, with just a small amount of fuel and pilot only, the machine must be capable of getting off from a small lake situated at a high altitude and must possess rapid climb under these conditions. This quality is essential to take care of the case when a machine is forced to land in a small and badly situated lake, so that by lightening the machine the pilot can get it out of the lake and land in some more suitable spot later. A machine of this type is useless during six months in the year, when the lakes and rivers are closed to navigation, and one question to be decided is whether it is possible to fit some sort of ski landing gear on the lines of an amphibian landing gear that would make a flying boat suitable for use in the winter.

In the prairie country, the work up to the present has consisted mainly of forestry patrol along the eastern slopes of the Rocky Mountains. In this district, aeroplanes have been used, and owing to the fact that landing grounds are situated at a high altitude and that the flying conditions are very abnormal, due to the great height of the peaks that have to be negotiated and the varying wind currents, it has been found desirable to use a single-seater scout of rather special type. This single-seater machine must have a very low landing speed, as it is desirable that the machines should work from aerodromes situated in the foothills close to the district to be patrolled. In these districts the aerodromes would necessarily be very small and situated at a great altitude above sea level, which condition would necessitate a low landing speed for the machines, a requirement which is further called for by the fact that any forced landing would be on the side of a heavily timbered mountain or in a lake.

FIG. 12.
*Typical lake country.*

Another requirement for this machine is high rate of climb. This is called for, not only for clearing obstacles immediately after leaving the aerodrome, but also to meet the case where a machine may be trying to fly out of a valley but actually be climbing in a rapidly descending air current, with the result that unless the machine has a good performance it may actually lose instead of gaining height. The question of top speed is of very small importance, as for forest patrol work it is not necessary to have enormous speeds such as would be called for with a fighting scout. The only condition requiring high speed is that the machine must be able to negotiate any adverse winds likely to be experienced. From the above description it is seen that a modern fighting scout is quite unsuitable for this type of work.

The pilot must be provided with some means of communication with the ground, and for this purpose wireless telephony would appear to be most suitable, as it enables the pilot to communicate immediately and explain the condition of a fire that he may observe, and otherwise direct any fire-fighting operations that may be started. In this district the work has been mainly fire patrol, and consequently the necessity for winter flying has not arisen; but it is anticipated that a standard land machine fitted with skiis instead of wheels will be able to meet the conditions.

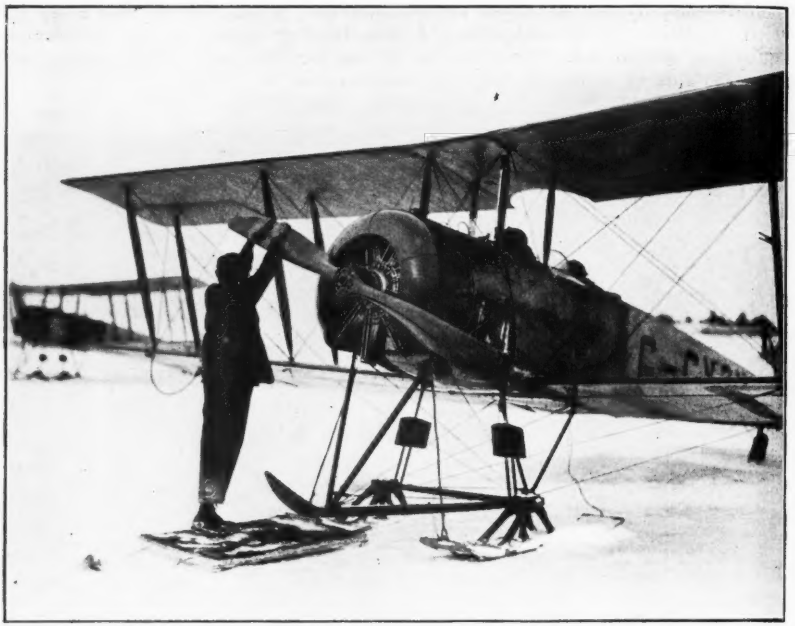

FIG. 13.
*Propeller swinging. Note mat.*

## WINTER FLYING.

The problems connected with winter flying may be divided into two parts:—

1. Those dealing with the power plant.
2. Those dealing with the rest of the machine.

Power plant problems may be again subdivided as follows:—

(*a*) Engine cooling.
(*b*) Engine lubrication.
(*c*) Engine starting.
(*d*) Propellers.

## ENGINE COOLING.

### Air-cooled Engine.

Any person who has operated an automobile during the winter months in Canada will appreciate the advantages of a satisfactory air-cooled engine. There

is no doubt whatever that when flying becomes general in this country the air-cooled engine will be universally employed, as the difficulties experienced with a water-cooled engine are so numerous that the time occupied in looking after the power plant is excessive. It is, in fact, practically impossible to use a water-cooled engine during conditions of extreme cold, but as in most countries a temporary cold spell may be experienced at any time, it is essential that experience on a water-cooled engine should be obtained even under the most difficult conditions.

With an air-cooled engine there are quite a number of points that require attention and care, more particularly with regard to lubrication.

**Water-cooled Engine.**

As the standard high-powered aero engines are at present water cooled, it has been necessary during the last few years to determine the most satisfactory

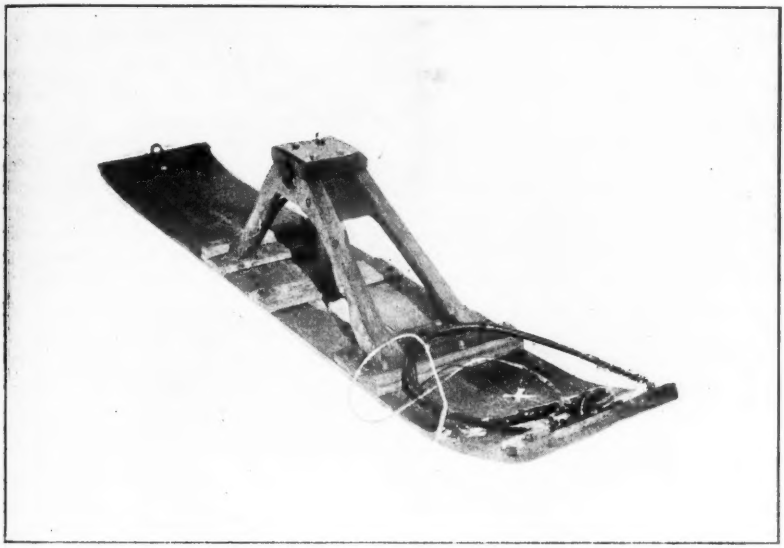

FIG. 14.

*Ski for Curtiss machine, as used for training during the war.*

way of operating these engines in the winter. To appreciate fully the difficulties that are likely to be experienced it is necessary to consider the case of an aeroplane that is forced to land during the winter at some place where there is no hangar accommodation. On landing it is necessary for the whole cooling system to be drained of water immediately, and in order to be certain that there is no water or ice left in the water pump, or in other parts in the system, it is generally advisable to apply hot-water rags, or some other means of heating, to the system until all draining has ceased. When it is required to again start the engine it is necessary to fill the water system and obtain a free circulation of water without the obstruction of any ice, which is by no means an easy proposition.

**Radiator Systems.**

If the radiator system of a water-cooled engine is correctly proportioned and is provided with shutters covering the whole area of the tubes, there is usually very little difficulty when the machine has been correctly started up and during the time that it is in flight; but on landing, or stopping the engine, and during the process of filling and warming up from the cold, the present form of honeycomb radiator is likely to cause very considerable trouble. It has been found that any water left in the bottom of a radiator and allowed to freeze causes a fracture of the tube, and the leak is usually not discovered until the machine has been filled again and warmed up for the next flight.

It would appear to be desirable, therefore, to consider the adoption of a radiator system which allows for—

(1) A variation of area to suit the difference between summer and winter conditions, and

(2) The adoption of some form of tube system which is not liable to fracture when ice is accidentally formed.

**Anti-freeze Mixtures.**

A good deal of work has been carried out on anti-freeze mixtures, and owners of automobiles will appreciate the limitations of these mixtures due to the fact that any accidental overheating of the engine drives off the more volatile parts of the mixture and results in leaving a mixture in the system, which is of unknown composition and may be liable to freeze. If a really reliable anti-freeze mixture could be obtained, the difficulties in connection with a water-cooled engine would be very largely overcome, but the mixture must be such that by some simple means, such as by taking its density, it is always possible to determine exactly what amount of alcohol or other substance must be added to bring the mixture back to its original consistency.

Another difficulty with anti-freeze mixtures which has not been thoroughly cleared up is the unknown factor of the effect of the highly inflammable gas which is given off from the cooling system while the engine is running. There are so many fire risks in connection with a gasoline engine that it is always undesirable to introduce a further possible source of trouble.

**Cowling.**

The cowling for aero engines to be used during winter flying requires to be carefully designed. It must be easily removable by a man working in thick gloves, and the fastenings must be such that they can be handled under these conditions.

Further, in the case of an air-cooled engine the cowling must be so designed that the amount of air passing over the engine can be varied to suit different weather conditions.

## ENGINE LUBRICATION.

**Oil Tanks.**

In cases where aero engines are provided with an oil supply sufficient to last for a considerable number of hours it is very undesirable that the main oil supply should all be in circulation at one time, and, therefore, during the latter stages of the war it was usual for the oil tank to be so divided that one or two gallons of oil were in circulation through the engine and the remainder was simply available for making-up purposes. This method of installation is a matter of absolute necessity when dealing with low temperatures, for when starting up it is necessary to run the engine carefully until a reasonable low oil pressure has been obtained, which would not occur until the oil in circulation

has been warmed up sufficiently. If all the oil in the tank is in circulation, this warming-up process takes up too much time. In some cases it may be necessary to fit lagging to the oil tanks so that when once the oil has been warmed up its temperature can be maintained. This, however, can only be an experimental feature made to suit a particular machine.

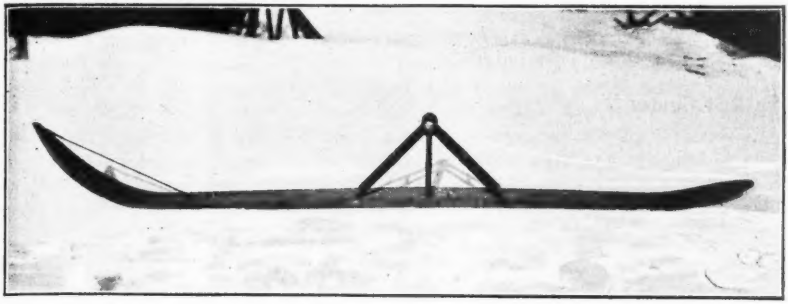

FIG. 15.
*Ski for Avro machine.*

In some cases it is desirable to arrange for some method of heating the oil tank whilst the machine is standing idle. This saves a lot of time otherwise wasted in heating the oil before starting, but it is difficult to arrange a heater which would be suitable for use when the machine was away from its base. In a hangar the heating can be conveniently done by means of small electric heaters lowered into the oil tank from the filler cap.

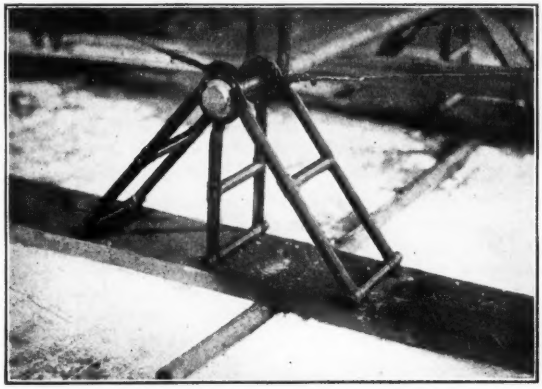

FIG. 16.
*Avro fitting slightly modified.*

**Oil Pumps.**

If an aeroplane is forced to remain for any time away from a heated shed it is usually necessary to give some attention to the oil pump. The most convenient way of doing this is usually to drain all the oil pipes, pumps, etc., as soon as the engine has stopped.

If the pumps are allowed to stand without draining, fracture is liable to occur on starting up due to the congealed oil in the bottom of the pump.

**Pipes.**

From experimental work carried out during last winter it would seem to be desirable to fit some form of pressure relief valve in the oil system to take care of the excess pressures that exist when starting up from the cold.

All pipes should be so arranged that they can be drained through cocks or plugs placed at the lowest points.

**Valve Rod Guides.**

In the case of rotary engines started from the cold it has been found that the main difficulty has been with the lubrication of the valve rod guides. As a rule these stick up, and in some cases the engine has back-fired into the carburettor due to the inlet valve remaining open. It is always advisable to have a fire extinguisher available when starting a cold engine for this reason.

**Oils.**

From the usual experience of internal combustion engines it would seem to be probable that aero engines will require a lighter oil for lubrication purposes during the winter, but the amount of work so far undertaken has not been sufficient to allow any standard recommendations to be made yet.

## ENGINE STARTING.

To return to the case of the hypothetical machine which has landed during the winter months in some district remote from an aerodrome, it is now proposed to consider the methods that would have to be adopted in order to get the engine started.

**Cranking.**

When a large engine has been left exposed to a very low temperature it is almost impossible for a man to turn the engine over by means of the hand starting gear, and much worse if he attempts to turn the engine by the propeller. It is, therefore, necessary to take some immediate steps to ease up the engine. With this end in view it has been found desirable to remove all the spark plugs and pour a certain amount of gasoline into each cylinder. Then turn the engine slowly for several revolutions until the pistons have eased up.

In the case of a smaller engine that requires to be turned by means of the propeller it is necessary to remember that in deep snow or on an icy surface the process of propeller swinging is even more dangerous than under ordinary conditions. It is essential that some form of mat should be provided for the man to stand on and also that his footgear is suitable for the existing conditions.

**Doping.**

In order to provide easy starts under varying conditions a number of experiments were carried out by Professor Robb of Edmonton, and as a result of these experiments Technical Memo. No. 29 was drawn up giving the most desirable mixtures of gasoline and ether for starting the engine under varying temperature conditions. A copy of this technical memo. is given as an appendix.

**Ignition.**

In the case of an engine provided with battery and coil ignition for starting, such as the Liberty engine, it is necessary that the battery should be removed from the machine at the time that the engine is stopped and kept at a temperature

of normal living quarters until it is required to start again. As it is essential that the battery should be well charged it is considered that a second battery is one of the most useful spare parts to carry. With magneto ignition it is necessary that the contact breakers and distributors should be carefully gone over to see that there has been no condensation and formation of ice. The spark plugs should be removed from the engine just before starting and heated up before being put back into the engine. In some cases it is known that a good engineer has removed the spark plugs from the engine immediately upon landing and fitted an old set, carried for the purpose, in the engine during the time that it was standing. The set of plugs that he proposed to use he always carried with him to his living quarters and kept them near a fire the whole time until they were required for use again.

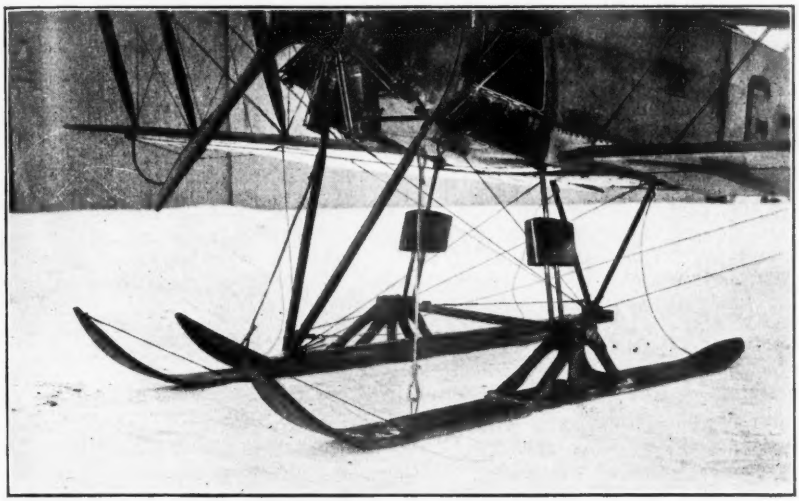

FIG. 17.
*Avro ski with Curtiss type fittings.*

**Filling Radiator.**

In the absence of a satisfactory anti-freeze mixture it is necessary to fill the cooling system with water. When setting out to start up the machine it is first necessary to provide an ample supply of hot water, and as soon as the engine has been started and warmed up slightly with the cooling system empty it should be stopped and the radiator system filled.

The process of filling up the cooling system with water is by no means an easy one. If this has not been done thoroughly the machine will probably be forced to land through the obstruction of the system within a very few minutes after leaving the ground. The best guide is, of course, experience of any particular type of machine with its known bad points in the system, but the principle to be followed is roughly given below.

The first thing to do is to open all the drain cocks or drain plugs in the system. These should, in fact, have been left open during the whole time that the machine had been standing. Pour in boiling water at the top of the radiator and allow it to flow through the system until the water leaving is itself very hot. No worse mistake can be made than filling up the system with the bottom plugs

in place as under the condition of extreme cold the water in the bottom of the radiator will always be found to be frozen. When the water issuing from the plugs and drain cocks is hot, pass the hand over all the pipes to see that there are no cold spots in any of the pipes. If a cold spot is found, this is probably due to a local piece of ice, and it will be necessary to thaw it out by means of rags dipped in boiling water or pieces of heated metal. Pass the hand all over the radiator to see that there are no cold spots on the radiator, as it is sometimes found that there will be a channel of warm water in one part of the radiator while the rest is all frozen. As soon as the cooling system is filled, restart the engine and gradually run it up to full speed. If boiling occurs in a very short time it is practically certain to be due to ice in some part of the cooling system, and the engine should be stopped immediately and the cooling system investigated.

### Filling Oil Systems.

Before any attempt is made to supple up or start the engine the oil system should be attended to. In most cases it is desirable that when the engine is stopped the oil should be drained completely and the system should be filled with warm oil when starting up. Experience with any one type of machine may modify this to the extent that it may only be necessary to remove the part of the oil which is going to be in circulation, and an oiling system could advantageously be designed so that it was possible to drain the oil from that part of the tank in the circulation of the engine without disturbing the main body of oil. This arrangement of oil tank may be desirable for other reasons as the oil in circulation may be carbonised and required to be renewed when the oil in the rest of the tank is in perfect condition.

## PROPELLERS.

### Formation of Ice.

It has been found that under certain conditions the propeller of an aeroplane engine becomes coated with a layer of ice along the leading edge. This layer of ice apparently goes on increasing in thickness until a portion of it becomes detached, which at once causes bad vibration of the engine until the remaining pieces of ice have become detached. Up to the present no method of overcoming this difficulty has been found.

### Metallic Protection.

For winter flying it is very desirable that a propeller should be sheathed with metal as protection against snow, hail, etc., but it is found that if the metal sheathing is put on in one piece it soon buckles under what appear to be temperature effects. It is essential, therefore, that the metal sheeting should be divided up so that there are no very long lengths without a joint.

## WINTER FLYING.

The problems connected with the remainder of the machine may be divided as follows :—

(*a*) Landing gear.
(*b*) Protection of crew.
(*c*) Temperature effects on rigging.
(*d*) Shrinkage of wood parts.
(*e*) Temperature effects on instruments.
(*f*) Temperature effects on shock absorbers.

## WINTER LANDING GEAR.

**For Aeroplanes.**

In a country as large as Canada there are wide variations in the winter conditions that are to be expected. In some districts there will usually be a lot of snow, while in other districts subject to much greater cold there will be hardly any snow at all. It is to be expected, therefore, that in certain parts it will be possible to use wheels, but before attempting to fly from one district to another it is essential to know the depth of snow that is likely to be experienced at the other place.

Districts that have different conditions of snow will also require different forms of winter landing gear. For instance, the skiis as normally used for snow of moderate depth were during last winter found to be quite useless in very deep snow for reasons given below. Skiis have been tried with areas varying

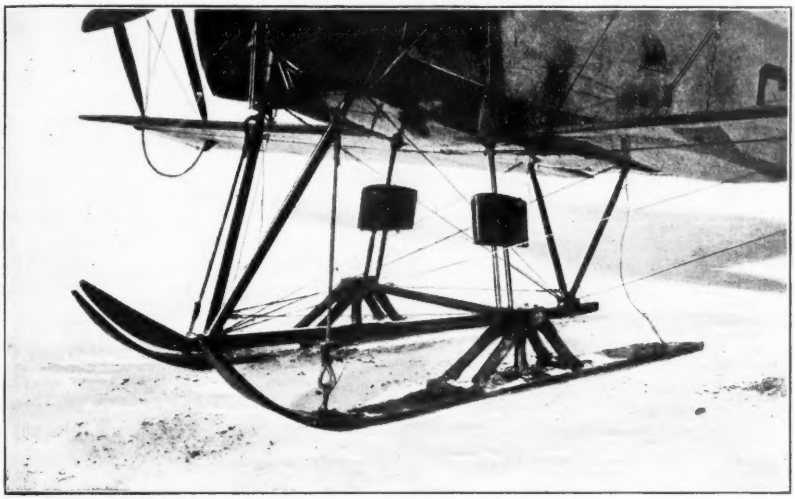

FIG. 18.

*Ski reduced in area by cutting off the rear end.*

from a loading of 90 lbs. per sq. ft. up to 200 lbs. to the sq. ft., and there is little doubt that for snow of a few inches' depth or for hard surface snow a loading as high as 200 lbs. per sq. ft. can be used satisfactorily.

Skiis require to be of normal form with an aspect ratio such that the length is approximately ten times the width. They should also be sprung; that is, arched at the centre, so that when standing on soft snow the skiis are flat and not bent down in the centre due to the load of the machine. Fore and aft grooves along the bottom surface of the skiis are believed to be of some value in maintaining the direction, but this is very indefinite.

The fitting from the ski board up to the axle should be easily removable, as the bottom boards very rapidly wear out. It is usual to fit check cables fore and aft to limit the rotation of the ski about the axle. These cables should have a length of rubber shock-absorber cord inserted so that they are kept tight under all conditions. One difficulty in connection with skiis is in breaking out when the machine is required to start, as by standing the ski becomes frozen into the surface of the snow. On some occasions it has been necessary to break

out the skiis by pushing the tail of the machine sideways, but this is very destructive on the fittings and a much better solution is to prevent the freezing of the skiis. Experiments have been made with various kinds of ski wax as usually sold, and it has been found to be satisfactory for this purpose. It is expensive, and some cheaper wax is required.

In designing the fittings for skiis it should be remembered that these are liable to be subjected to very large sideloads and especially to a twist when the ski is trying to run straight and the pilot has full rudder on trying to turn. It is considered that ski fittings should be designed for a horizontal load at the top of the fitting equal to half of the vertical load and to the same factor as is used for the vertical load.

In deep snow it is found that a flat board type of ski very quickly buries itself sideways if there is the slightest amount of side drift or turning while taxiing. In fact, in one particular case the machine buried itself up to the wings in soft snow although the ski had ample surface for its support. In order to prevent this digging in sideways it is necessary to have a certain amount of side area, and in consequence of this experience it has now been decided that whenever deep snow is likely to be encountered it will be necessary to use a ski which is much more like a float. In some ways this is not a disadvantage, as it will allow for a certain amount of fairing of the up-turned point, but the introduction of large side area may also require the addition of more fixed fin area at the tail of the machine.

When a machine is equipped with skiis it can be handled with more or less ease on a snow or ice surface; but if it is required to be housed in a heated shed some auxiliary means of handling is necessary. For this purpose it has been found that a three-wheeled garage jack, as used for moving automobiles, can be used with advantage, and there is plenty of scope for ingenious means of rapidly fitting wheels for taking the machines in and out of sheds.

An important item not to be forgotten is the fitting of a large spade-shaped ski to the tail skid. This is very satisfactory from the point of view of keeping the tail out of the snow, but owing to the low resistance to sliding a tail ski lacks the braking effect of an ordinary tail skid. It has been suggested that the tail skid should project through the tail ski for several inches so that if there is a crust on the snow the point of the tail skid would break through and give a breaking effect to the machine.

In the case of a very sandy aerodrome it has been found advantageous to leave the winter tail ski of the machine for use in the summer so as to avoid cutting up the sandy surface.

### Float Seaplanes.

It has been suggested that float seaplanes could be used for winter landing by fitting a ski board to the lower surface of the floats. This, however, does not appear to be feasible owing to the fact that the bottom of the float does not change its angle to the rest of the machine whereas a ski requires very considerable changes of angle.

For a float seaplane it is suggested that the float should be entirely removed and winter landing gear fitted, as it is only for a very short period that the machine may be required to act as an amphibian. During the winter all landing is on snow or ice, and during the summer all landings can be made on water.

### Flying Boat.

The flying boat has so many advantages for flying during the summer months that it would appear to be very desirable to provide a winter landing gear of the amphibian type rather than to do away with this type of machine.

This landing gear need not necessarily be convertible while in the air, but can simply be a ski attachment put on at the commencement of the winter. The problem is one which does not seem to involve any great difficulties, and it is certainly well worth trying.

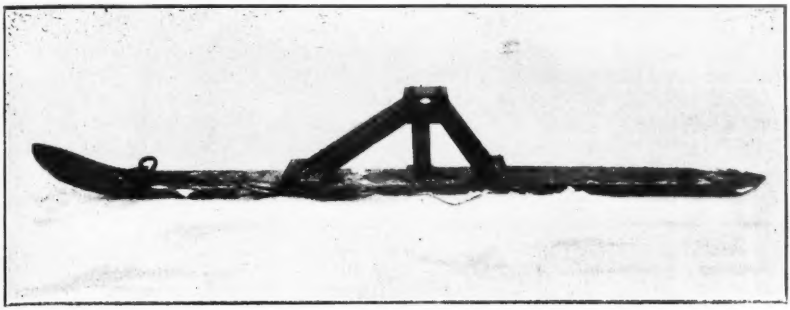

FIG. 19.
*Ski further reduced by cutting down the front.*

## PROTECTION OF CREW.

### Enclosed Cabin.

For the protection of the crew of the machine during the winter it is very desirable that some form of enclosed cabin should be fitted, but it is pointed out

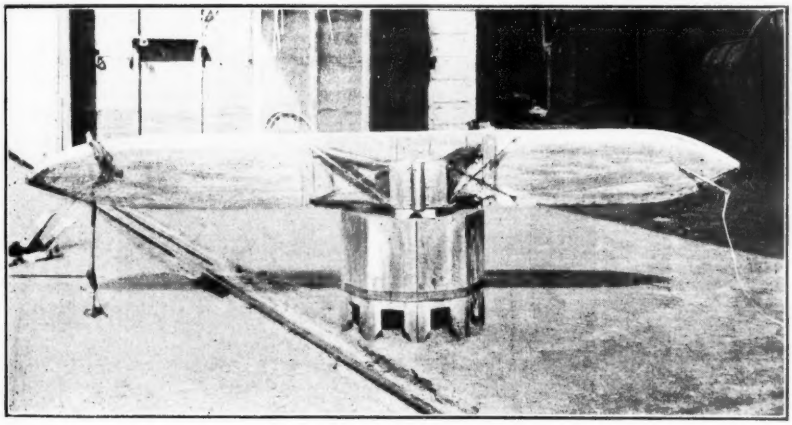

FIG. 20.
*Cross bracing added to Curtiss type fitting.*

that this cabin requires to be very carefully designed, and further, a lot of experimental work is necessary in this connection.

Experience on the passenger-carrying services in England has shown that the passenger cabin on a machine used for transportation purposes can be correctly ventilated for ordinary summer conditions, but under winter conditions the question of heating and ventilation is a very different problem. The design

of a cabin for members of the crew that are required to operate the machine is even more difficult as it is necessary to provide protection and at the same time give sufficient view and access to the other parts of the machine for the requirements of the crew. Anything in the nature of an ordinary window becomes fogged if the cabin is heated and the outside air is very cold. Therefore, all windows must be capable of being easily and rapidly cleaned.

It is regretted to say that up to the present very little work has been done along these lines, but it is a subject that requires urgent attention if any serious winter flying is to be carried out.

**Flying Clothing.**

The subject of flying clothing is so closely associated with the question of accommodation that the two must be studied together. If a heated cabin is provided for the passengers, then the flying clothing does not require so much attention; but it must be remembered that sufficiently heavy clothing must be available for the passengers when they leave the machine or in the event of the heating system failing. The old type of electrically-heated flying clothing as used during the war is not at all satisfactory for several reasons. In one type there is a heated coil in the middle of the person's back. If this is kept on, perspiration is often set up. The heater is then turned off, and in a very short time a mass of ice forms inside the clothing in the neighbourhood of the heater so that the person is kept alternately hot and cold. A solution would appear to be best found by providing a cabin which could be maintained at a uniform temperature of about 60°F. and by supplying fur robes for the occupants to wear when leaving the machine or when the heat is turned off.

**Helmets and Goggles.**

These are very closely connected with the previous two subjects, and should be studied in connection with them. Tinted goggles are necessary to prevent eye strain due to the glare set up from a snow surface.

**Emergency Gear.**

Any machine flying away from railroads or settlements must be provided with emergency gear for the use of the personnel in the event of landing away from the base. This emergency gear must consist of two or three days' rations, rifle, snow shoes, warm clothing, etc., in order that the personnel can maintain themselves under the cold conditions.

## TEMPERATURE EFFECTS ON RIGGING.

It has been observed that there are more failures of streamline wires during the winter months than during the summer, but the reason has not been explained.

**Temperature Variations.**

If an aeroplane is kept in a heated shed at a temperature of about 60°F. and is then taken out into the open air with a temperature of below zero there will be some quite large stresses induced in the rigging due to the difference in the construction of the wood and metal parts. It has not yet been shown that these differences are sufficient to account for the increased number of failures, but it would appear to be desirable that the machine should be rigged under cold conditions.

This also applies to the case of a machine used for very high flying where the ground may be quite warm, but at a great height the temperature may be very cold indeed. It is not known whether failures have occurred in Europe under these conditions. It is hoped that some low temperature vibration tests on wires may also throw some light on this matter.

**Metal Construction.**

From the point of view of rigging and alignment, the advantages of metal construction would appear to be very great when a machine is likely to be subjected to extreme variations of temperature, but before the light alloys can be adopted with confidence it is desirable that experiments on vibration of light alloys at low temperatures should be carried out.

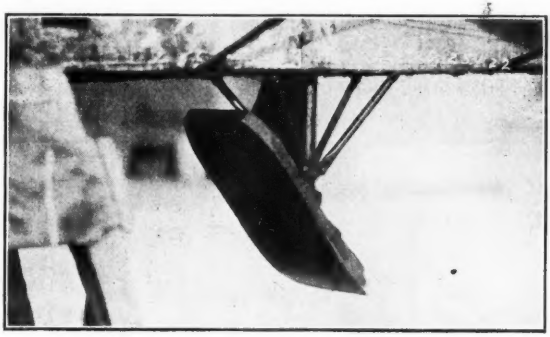

FIG. 21.
*Tail ski.*

## SHRINKAGE OF WOODEN PARTS.

When subjected to very low temperatures the air becomes abnormally dry, and it is has been found that, however well protected with varnish, wooden parts tend to dry up and shrink. This condition is also found during the summer

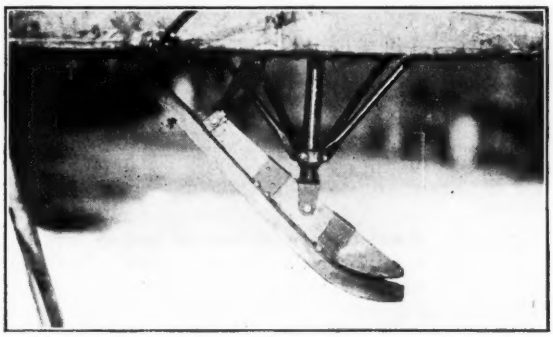

FIG. 22.
*Tail ski.*

months in the prairie country, and therefore it would seem to be necessary that while wood is still used in aeroplane construction, the parts should be manufactured in the district in which they are required to be used. It has been found that a wooden spar of about 3½ inches' depth will contract in depth sufficiently to break the flanges of all the ribs, or to pull away from all the ribs, with the result that it becomes imperative to open up planes at least once a year to see the condition of their spars and ribs.

It is also found that all metal fittings encircling wooden parts become loose and require tightening. This difficulty with the use of wood is another very strong reason in favour of metal construction, and with this end in view it is desirable that as much experimental information on metal construction should be obtained as possible.

## TEMPERATURE EFFECTS ON INSTRUMENTS.

### Air Speed Indicators.

Owing to the difficulties experienced with rubber under low temperature conditions it was anticipated that an air-speed indicator with a rubber diaphragm

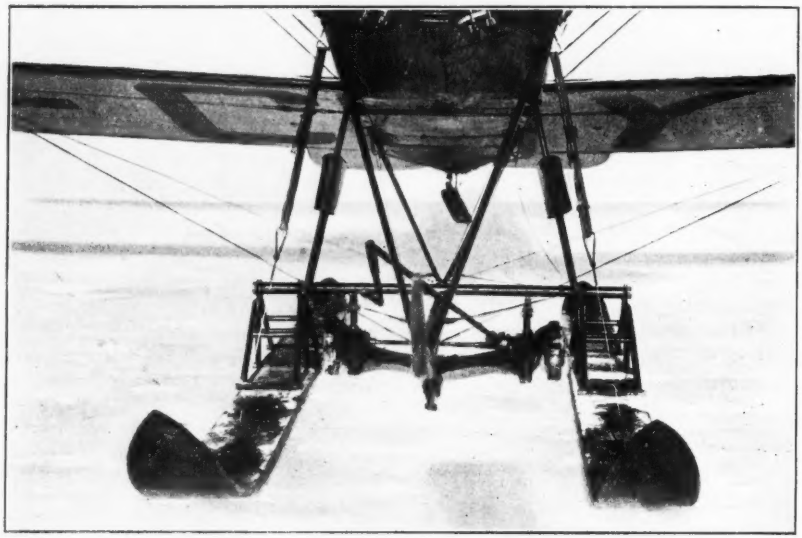

FIG. 23.
*Garage jack for handling in sheds.*

would be unsatisfactory. Some tests were carried out to investigate this, and it was found that although a rubber diaphragm air-speed indicator was a little sluggish at low temperatures it did not actually cease to function until a temperature of —60°F. was reached when the diaphragm ceased to work. From this it would appear probable that a rubber diaphragm air-speed indicator would not usually give any trouble at the temperatures likely to be met, but it has been found that an occasional air-speed indicator of this type will cease to function. At a temperature of around 0°F. this effect is believed to be due to the mechanism rather than to the diaphragm. A comparison carried out between a steel diaphragm indicator and a rubber diaphragm has shown that more reliable results can be obtained from the steel diaphragm indicator as it is less sluggish, the readings up and down the scale are more nearly the same, and no temperature effect down to —100°F. has been found.

The possible stoppage of the usual form of pitot head by ice must also be considered, with the result that it will probably be necessary to use a ventive tube with orifice sufficiently large to prevent stoppage.

**Revolution Indicators, etc.**

No bad defects of these instruments have yet been reported, but it is anticipated that lubrication troubles, particularly with long flexible shafts, are likely to be experienced.

**Temperature Effects on Shock Absorbers.**

When landing on ground under cold conditions it is found that there are more failures of shock absorbers, axles, etc., than in the summer. This may be attributed to one or both of two causes :—

1. The hardness of the ground.
2. The temperature effect on rubber.

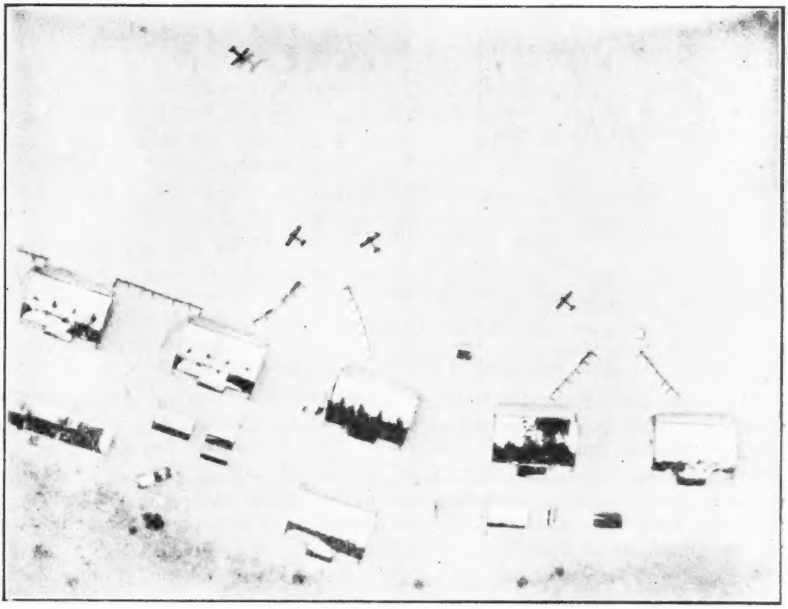

FIG. 24.
*Snow fences around hangars.*

In order to determine the effect of temperature on rubber shock absorbers some experiments have been started on the qualities of this material under low temperatures, and it is anticipated that it will be necessary to rewind shock absorbers for use in the winter.

## LANDING ON SNOW.

It has been found to be very difficult to judge the height of the machine when landing on a clear snow surface, and, therefore, if flying is to be carried out around an aerodrome it is essential that the surface of the snow should be cut up by taxiing the machine around the aerodrome before flying commences. In the case of landing on a snow surface which has not been cut up it is necessary for the pilot to take as much advantage as possible of any surrounding objects, such as trees, in order to get an indication of the height above the

ground. This effect will, of course, be the same as that experienced with landing a seaplane on water which is perfectly smooth.

**Snow Fences.**

There will, of course, be a large number of other questions dealing with snow conditions which require attention. A particular case is the necessity for the prevention of snow from drifting up around the hangar doors, and some form of snow fencing is usually necessary to prevent this.

## CONCLUSION.

Up to the present it has not been possible to do more than to consider the problem of winter flying and to start such researches as circumstances permit. The Honorary Advisory Council for Scientific and Industrial Research formed an Associate Air Research Committee, and it is due to this Committee that the research work mentioned above has been carried out.

In addition to this a good deal of the experimental work on winter flying has been carried out at Camp Borden under the direction of the Officer Commanding, Canadian Air Force.

## APPENDIX.

THE AIR BOARD.

OTTAWA, ONT.

TECHNICAL MEMORANDUM No. 29

(Cancelling Technical Memos. Nos. 2 and 15).

*Re* **Starting Aero Engines at Low Temperatures.**

The work carried out by Professor Robb at Edmonton during this season and last can now be summarised in the form of a procedure for starting aero engines at various low temperatures.

The problem, as presented to Professor Robb, was that he was to assume that the engine was in an aeroplane which was forced to spend a night in the open away from the base, and it was desired to know the best method that the crew should adopt in order to start the engine the following day.

It is assumed that while the engine has been still hot the cooling system has been completely drained, or that an efficient anti-freeze mixture is available. It is also assumed that the battery has been removed from the machine and kept at ordinary room temperature, and also that a supply of commercial ether at room temperature is available.

The first operation is to ease up the motor by doping with about one half-pint of gasoline and turning the engine over until it is quite free. In this connection it is important to see that there is no ice in the water pump before any attempt is made to turn the engine over.

The next operation is to dope the engine with about one quarter of a pint of a mixture of ether and gasoline. The mixture which is most suitable to different temperatures is given in a list below.

It is important that this initial doping should not be too liberal as it has been found that if the doping is slightly increased the engine does not start well.

As soon as the engine starts to fire, an additional one quarter of a pint of the mixture is pumped into the intake manifolds, and this should suffice for the engine to begin to fire on gasoline from the carburettor, which has been flooded meanwhile.

The motor is allowed to run for about two minutes until it is warm enough to take water at ordinary room temperatures, but care must be taken that the engine is not run too long without water.

As soon as the cooling system has been filled the engine should be started again and run for some little time to see that the cooling system is functioning properly.

If the engine starts to boil in an unduly short time, examination should be made for an accumulation of ice that may have stopped the system.

Experiments will be carried out on the best method for handling the oiling system, but at present it is considered advisable to drain the engine immediately on landing and fill it up with oil at at least room temperature when commencing to start. It is essential that the battery should be charged to specific gravity of over 1.25, and this suggests an extra battery should be carried. (The experiments were carried out on a Liberty engine. If the engine is fitted with magnetos, care should be taken to see that the contact points and the distributor are clean and in good order before attempting to start.)

The priming nozzles serving the intake manifolds must be sufficiently large to permit liberal doping quickly, and in the case of a second cold start being required soon after the first, care should be taken to see that these nozzles have not become frozen up.

The priming device requires to have sufficient capacity to permit quick doping with ether mixture, and the storage tank to serve the priming pump should have capacity for at least one half-pint of mixture to permit two dopings.

Professor Robb used a pump constructed from a grease gun which had a bore of 1⅛ins. and a stroke of 7ins., and he states that a standard priming pump is too slow for this particular service.

Professor Robb experienced no difficulty with the spark plugs in almost 100 starts, but it is considered advisable to remove the plugs from the engine and heat them over a fire before attempting to start.

The proportions of the mixture for doping, suitable for different temperatures, is as follows :—

| Temperature. | Gasoline. | | Ether. |
|---|---|---|---|
| + 20°F. and above. | Pure. | | |
| Zero to 20°F. | 3 | to | 1 |
| — 15°F. to Zero. | 2 | to | 1 |
| — 30°F. to — 15°F. | 1 | to | 1 |
| — 37°F. | | | Pure (Warm). |

At the higher temperatures it has not been necessary to warm the mixture, but a start at — 37°F. indicates that at this temperature ether requires to be warm, that is, at room temperature. The carburettor should be flooded in all cases before starting, and the spark should be advanced immediately the engine begins to fire. The usual position of the throttle for starting the Liberty engine is about 1/5th open.

The ether used in these tests has been put up in one pound sealed tins marked " Mallinchrodt Motor Ether."

In connection with this research a number of interesting points have been raised, and it is suggested that if any further information is required, application should be made to the Secretary of the Air Board.

(*Sgd.*) E. W. STEDMAN,
Director of Technical and Stores' Sections.

23/1/22.

## CORRESPONDENCE.

*To the Editor of the* AËRONAUTICAL JOURNAL.

DEAR SIR,—With reference to Captain de Haviland's very interesting paper on the Design of a Commercial Aeroplane, reported in your last month's issue, I should like to make the following comments upon the author's attitude towards all-metal aircraft.

Firstly, I can quite understand that there is no argument for immediately introducing all-metal machines into these services. Captain de Haviland and Mr. Handley Page are both engaged in the very difficult problem of making commercial air services financially successful, and since wooden built machines are quite satisfactory for their present requirements, there is no reason to "swop horses in the middle of the stream."

This fact, however, is no argument for belittling the merits of all-metal construction as a whole, nor for assuming that it will be many years before the all-metal machine replaces the old type of construction.

At the present time my firm is in the unique position of being the only firm in this country which has built and flown an all-metal aeroplane, and I am therefore able to speak from actual experience.

Our machine was designed, built and flown within the space of six months, which is sufficient refutation of the idea that all-metal machines are difficult to build. Broadly speaking, I should put down the advantages of our all-metal machine as follows:—

Greater strength for a given weight of structure, less liability of damage to the structure in the event of a bad landing, absolute fireproofness, greater rigidity of the plane surfaces, which becomes increasingly important in view of the high speeds (and consequently high air pressures) which are being attained to-day. The ease with which fireproof bulkheads are inserted in the fuselage, great cleanliness of design, permitting of ready inspection of the interiors of planes and fuselage. (It is possible to take off a plate of the wing covering and replace it in a very short space of time, roughly thirty to forty-five minutes.)

It is quite certain that a metal monocoque fuselage lends itself more readily to mass production than does a wooden fuselage of the same type, whilst it is less likely to be damaged and easier to repair in the event of damage.

We found that we could build our fuselage in several separate segments, completely finishing the details of these segments and then rivetting them together in a very short space of time.

Finally, there is the undoubted fact that an all-metal machine will weather better than one of wood and fabric.

So far as fighting aircraft are concerned, I am convinced that the all-metal machine will entirely replace the older form of construction and that in a very short space of time.

I do not wish to create any misunderstanding as regards the weight of metal-covered plane surfaces; it seems to me that it will always be possible to build a plane with metal structure covered with linen fabric, lighter than a similar plane covered with sheet metal, but the difference is not so great as some people imagine, it is about 2/10ths-lbs. per sq. ft., and this figure is capable of reduction in the future when thinner gauges of metal are made.

Yours faithfully,
OSWALD SHORT.

Whitehall House,
29-30, Charing Cross, London, S.W.1,
11th August, 1922.

[Further correspondence on the all-metal aeroplane is invited.—EDITOR.]

# REVIEW.

**The Airplane Engine.** By Lionel S. Marks (Professor of Mechanical Engineering, Harvard University). McGraw-Hill Book Co., Ltd. 30s. net.

The great struggle between the belligerent nations for supremacy in the air during the war can be truthfully stated to have been largely concentrated around the development of high performance and reliable types of aircraft engines.

In order to accomplish the results attained, which under normal conditions would probably have taken at least three or four times as long, a tremendous amount of development and research work was necessary.

This work was almost exclusively carried out under the auspices of the various governments concerned; but owing, however, to the conditions under which it was conducted and the veil of secrecy with which it was naturally shrouded, the results obtained were not available for publication until the last year or two and then only in disconnected form in the shape of many important papers given before the various learned societies or in the pages of the various periodicals which make a feature of this type of work.

Professor Marks is therefore to be congratulated on this volume, which in his introduction he states attempts two things, viz. :—" To formulate existing knowledge of the functioning of the airplane engine and its auxiliaries; and to present and discuss the essential constructive details of those engines whose excellence has resulted in their survival," and which does in effect summarise and present in a very readable and comprehensive form the conclusions reached as a result of the research work previously referred to.

The book contains nineteen chapters, a good index and 349 illustrations, and a total of 454 pages.

The illustrations are particularly good, comprising as they do many detailed working drawings and diagrams of some of the most modern aircraft engines of all types and of all nations.

The first three chapters deal with the power required for flight, engine efficiencies and capacities and engine dynamics respectively.

The next chapter, which treats of engine dimensions and arrangements, deserves special mention, as it contains a series of tables which cannot fail to be of great value to designers and all other workers connected with the aircraft engine industry, viz., full particulars of the general and detailed dimensions of various types of modern aircraft engines selected for their proved reliability and performance.

The subject of materials is next dealt with, and as it is a well-known fact that it is largely the enormous strides made with materials, especially alloy steels and aluminium alloys, that have made the modern aircraft engine possible, the particulars given of the materials recommended for all engine parts are of great interest.

The design of engine details, valves and valve gear and a general discussion of radial and rotary engines are next considered, and it is interesting to note in connection with the last-mentioned chapter, the pre-eminence of the air-cooled static radial engine, a design which has been largely fostered by the British Government and which undoubtedly gives higher performances from the power-for-weight point of view than any other type of aircraft engine.

In view of the necessity for utilising high compression ratios in modern aircraft engines in order to obtain efficiency, the subject of fuels and explosive mixtures which is next dealt with is of very great importance and is one around which discussion centres very largely nowadays. It is pleasing to note, therefore, that

the work of Ricardo, who has done so much towards eliminating the trouble with "detonation" or "pinking" experienced when using standard fuels in high compression engines, is given prominence.

The carburettor, fuel systems, ignition, lubrication and the cooling system are next dealt with. The last-mentioned chapter is of particular importance, including as it does a very useful discussion on air cooling and details of the design of fins for maximum efficiency. A large amount of research work on air cooling has been carried out during the last few years, especially by the British Government; but a lot remains to be done before it can be definitely stated that air cooling is preferable to water cooling in all fields, although for certain purposes, *e.g.*, the high performance military machines, the air-cooled engine has the preference.

The last few chapters are devoted to geared propeller drives, supercharging, manifolds and mufflers, starting and potential developments.

The chapter on supercharging is of great interest, for the loss of power with altitude, which is a feature of the internal combustion engine, is a great drawback from the military point of view, and most nations have concentrated on researching into the possibilities of maintaining engine power from ground level to a predetermined altitude.

The chapter on potential developments is a general review of the situation regarding aero engine design as it stands at present and an indication of possible developments in the future, which should serve as a stimulus to research workers and designers to carry on the good work of developing the aircraft engine until it is thoroughly reliable and can be truthfully stated to be the means of ensuring cheap and reliable transport by air.

F. A. F.